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Sediment Management Methods to Reduce Dredging: Part 2, Sediment Collector Technology

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PURPOSE: This Dredging Operations and Environmental Research (DOER) Program technical note (TN) is the second in a series evaluating sediment management methods to reduce dredging through a research task (RT) in the DOER Program.[1] This TN presents an evaluation of sediment collector technology, one promising new device that may help better manage sediments to reduce traditional dredging requirements.

INTRODUCTION: The first of two technologies being evaluated under this RT is a sediment collector currently installed in Fountain Creek, Pueblo, CO, (location shown in Figure 1) intended to demonstrate technology to alleviate the need for dredging by lowering the downstream grade to reduce flooding and ultimately reduce sediment deposition as far downstream as John Martin Reservoir, a U.S. Army Corps of Engineers (USACE)-managed lake. The system operates on the principle that sediment in bedload can be trapped by gravity and removed at the natural rate of transport, instead of episodically. This DOER TN describes the technology and installation at Fountain Creek, other possible applications, lessons learned, cost, and provides some general guidance for applying collector technology at other sites.

Figure 1. Location of sediment collector.

COLLECTOR INSTALLATION IN FOUNTAIN CREEK: A 30 ft wide, high-capacity sediment collector was installed in Fountain Creek, Pueblo, CO, upstream of the confluence with the Arkansas River in July 2011 (Figures 1, 2, 3, and 4) to demonstrate the viability of this new technology.

[1] Thomas, R. C., and T. Welp. In preparation. Sediment management methods to reduce dredging: Part 1, sediment minimization concept and demonstration project introduction and overview. DOER Technical Notes Collection. Vicksburg, MS: U.S. Army Engineer Research and Development Center. www.wes.army.mil/el/dots/doer

Figure 2. Sediment collector installed in Fountain Creek.

Figure 3. Archimedes screw separator (left) and stacker (right).

Figure 4. Electronic control panel and Archimedes screw separator.

The sediment collector system, as installed in Fountain Creek, consists of six main parts:

1. collector: 30 ft wide bedload collector
2. pump: 50 HP, submersible variable frequency drive (VFD) pump
3. controller: electronic controls with internet access and remote interface
4. 6 in. discharge and 8 in. water return DR 11 (160 pounds per square inch [psi]) high-density polyethylene (HDPE) pipelines
5. sediment separator: 100 tons/hour (hr)
6. stacker: capable of storing approximately 1,000 cubic yards (yd^3).

The primary component of the collector is a steel hopper (Figures 2 and 5) placed on the bottom along a sediment transport pathway. A manifold system inside the hopper focuses flow across a small region within the hopper, providing high velocities needed to entrain sediment. A dredge pump housed in the hull with the hopper pumps water and sediment through the manifold to the placement area. The pump can also be mounted remotely on land, the preferred configuration for maintenance. Booster pumps can be added to increase the pumping distance, as required.

Figure 5. Installation of 30 ft long collector.

The system can be operated in an open or closed cycle. In the open cycle, water is drawn into the collector manifold from across the screen. Since the area of the screen openings is much greater than the area of the manifold orifices, velocity across the screen is very small (<1 feet per second [ft/sec]), even though velocity at the manifold is large enough to transport sediment. In the closed cycle, the slurry is discharged into a holding tank and separated from the water, and then the water is returned to the opposite side of the manifold so that water is drawn from the holding tank instead of across the screen. Advantages of the closed cycle include minimal impingement velocity (reducing potential for clogging) on the hopper screen, reduced risk of entrainment of aquatic organisms, and greatly reduced consumptive water loss. Sediment is discharged into a bin at the

base of the screw separator (Figures 3 and 4), which separates and drops the coarse sediment onto the stacker (Figure 3). Sediment is stockpiled at the stacker until it can be trucked away.

Electronic controls enable automatic or remote operation, reducing or eliminating the cost of labor to supervise operation. The system can be set to run at specified times, as a function of stream gage data or as a function of hopper capacity (still in development). Dredge pumps, piping, separators, and stackers are off-the-shelf technology used in dredging and other industries with documented performance metrics.

OTHER POTENTIAL APPLICATIONS: Collector technology adds two key improvements over other installed dredging systems:

Selective capture. Both the size and quantity of sediment removed can be selected. Since the system operates with very low or no head across the screen into the hopper, only sediments coarse enough to be transported in bedload are trapped (fine sands to gravels), while finer sediments (silts and clays) remain in suspension. The top size of the sediment is limited by screen opening size. The total volume captured can be modified by controlling the duration of system operation and by varying the width of the collector installed.

Removal at the natural transport rate. At maximum production, the system is only capable of removing sediment at the total maximum natural transport rate. The collector is only capable of trapping sediments when they are supplied by natural forcing (currents or waves). Therefore, the system (when installed at grade) can never exceed natural transport processes. Removing sediment at the natural rate more closely mimics nature, reducing known and potential unforeseen environmental impacts. A permanent collector serves as a grade-control structure. When installed above grade on a complete cross section, the collector will cause aggradation upstream to the desired new elevation. When installed below grade, the collector will initiate a controlled-depth headcut upstream.

The selective capture of bed load at the natural transport rate leads to some specific new capabilities. Although not exhaustive, some potential applications for collector technology are discussed below:

- **Watershed management.** By actively managing sediments at the watershed level, it is possible to drastically reduce sediment load to the area or channel of interest. Managing sediments at many locations throughout the watershed may optimize habitat restoration and protection and also be more cost effective and environmentally friendly than the traditional practice of dredging at the problem site. This also presents an opportunity to take advantage of flexibility in siting, by helping to address issues with property ownership, road access, material handling and transportation, power availability, etc. Collectors are scalable to any stream width and can be readily retrofitted to existing cross-vane or other structures. They also allow users to actively manage grades in the vicinity of the collector.

- **Reduce quantity of contaminated sediment dredging.** Coarse sediments can be removed before being deposited in an area known to be contaminated, by reducing the total volume of sediment that must be dredged and placed under more stringent requirements typical for removing contaminated sediments.

- **Sediment bypassing.** At inlets in tidal systems, or other locations where there is a clearly defined sediment pathway crossing a navigation channel, a collector could be installed as a sediment bypassing system, allowing sediment to be removed and pumped past the navigation channel, and preventing deposition. The system would be installed at reaches where deposition is typical and the discharge located in an area with potential for scour or transport away from the channel.

  Reservoir sedimentation can be reduced by capturing and removing bedload at tributary mouths and either removing the material or reintroducing the sediment below the dam (at the natural transport rate, to offset channel and habitat degradation due to a sediment deficit caused by reservoir trap efficiency). Using collectors to design or retrofit sustainable reservoirs will not only reduce dredging requirements but will help maintain reservoir storage capacity and related hydroelectric generating capacity and reduce flood risks that would otherwise increase with a loss of storage.

- **Sediment backpassing.** On beach locations that experience accretion, the collector could be installed as a sediment backpassing system, allowing sediment to be removed from the accretion area and pumped back to beach erosional *hotspots* within practical pumping distance.

- **Application in remote locations.** Since a collector system can be installed with standard truckable equipment, it offers the potential for application in remote locations where there is a need to control grade in streams, to prevent downstream migration of excess or contaminated sediments, to maintain a navigable channel, or to supply coarse sediment with lower impact than traditional mining practices. In many headwater locations (e.g., first- or second-order streams impacted by logging, agriculture, or road construction), stream gradient may allow for collector clearing on a siphon basis for continuous operation with no pump or power requirement.

In addition to the potential applications listed above, implementation of this new technology could result in other benefits not yet fully investigated. Since there is essentially no flow into the hopper (with a closed water cycle), there is little risk of ingesting wildlife or foreign material that might clog the pump. This may help to meet permit requirements or avoid the need for some permits. Closed-cycle operations may also be used to address water rights issues by returning water to the hopper. Aesthetic impacts of dredging and operational limits (e.g., due to Threatened and Endangered species (T&E) or spawning seasons) could be avoided since there is very low or no flow into the system.

DEMONSTRATION PROJECT COST: Component, installation, and total cost of the system installed at Fountain Creek are listed in Table 1. The project was championed by the City of Pueblo and funded through the U.S. Environmental Protection Agency; Colorado Department of Public Health and Environment, Non-Point Source Office; Pueblo County; U.S. Department of Agriculture, Natural Resources Conservation Service; and Colorado Water Conservation Board (CWCB) in collaboration with the equipment developer Streamside Systems, LLC. Since the initiation of the project, the Fountain Creek Watershed, Flood Control, and Greenway District was created.

Costs shown in Table 1 approximate the actual system cost. Others have reported the cost to range from \$500,000 to \$1,000,000, although details associated with the higher estimates of cost are unavailable.

Table 1. Sediment collector cost.	
Collector (pumps, controllers, pipe, etc.)	\$419,000.00
Sediment Stacker	\$39,000.00
Installation	\$110,000.00
Approximate Cost of Contract Documents	\$50,000.00
Upgrades/Repairs	\$10,000.00
Total	**\$628,000.00**

Cost of operating the system has been minimal since it has been operated for short periods of time only and because Streamside Systems personnel donated time to operate the system to collect needed data. The system is capable of being operated remotely; however, because of potential risk to human safety associated with the separator and stacker, the system was only operated under direct supervision. The system uses approximately 1,000 Watts per hour (1kWh) per minute of operation. If the system were run continuously for 1 year, electricity cost would be approximately \$52,560 (based on cost of \$0.10/kWh).

Minor repairs were required after the flood of September 2011. Record-breaking rainfall resulted in extreme flooding and record creek flows but did not damage the collector. Damage to an exposed junction box required repairs totaling \$1,765. The remaining cost for upgrades/repairs included a return flow pump and minor modification to the initial layout of the piping. An 1,800 gallon (gal) tank was added at the separator along with a pneumatically actuated valve that provides return prime water for the dredge pump at startup to ensure that the specific gravity of the slurry is managed.

PERFORMANCE: Monitoring of the demonstration project has been underway since installation. Parameters that were planned for measurement included stream bed elevation within one-half mile of the collector, water level, sediment removed, electricity usage, maintenance required, and hours in operation. Specific performance data were collected at various flow rates over approximately 500 hrs. Since the system was not operated continuously over many months and with the bedload transport continuing when the system was not in operation, short term stream bed elevation and coarsening impacts were overwhelmed. Therefore, stream bed elevation was not resurveyed at the end of the project.

Record breaking rainfall in September 2011 resulted in extreme flooding and record creek flows of 13,800 cubic feet per second (ft^3/sec). High water damaged the junction box, causing total down time of approximately 2.5 months while the City of Pueblo worked to get a repair contract executed. This flood demonstrated survivability of the system in an extreme event. Repair time was less than 1 day, once the repair contract was executed. Winterization (heat tracing and freeze protection) was not specified, and the system was not operated for approximately 2 months during the winter season.

Production rate was the key performance parameter measured. Prior to installation of the 30 ft bedload collector, a 2 ft bedload collector (Figure 6) was temporarily installed in Fountain Creek to estimate bedload transport extraction rates and assess optimal elevation for collector operation. The 2 ft collector pumped sediment into a drop box (Figure 6) that, in turn, allowed a 3 ft^3 container to be filled with the subsequent fill time noted to calculate a production rate. Sediment was collected over a 3-day duration with extraction rates at respective stream flows listed in Table 2. Assuming a linear extraction rate function for a longer collector, respective production rates were estimated for a 30 ft long collector and listed in Table 2 as well.

Figure 6. 2 ft collector and drop box used to estimate production rates.

Table 2. Measured 2 ft collector and estimated 30 ft collector extraction rates.

Stream Flow (ft^3/sec)	2 ft Collector Bedload Extraction Rates	Estimated 30 ft Collector Bedload Extraction Rate (yd^3/hr)
100	3 ft^3/26 min	2.6
120	3 ft^3/38 min	3.8
600	3 ft^3/6 min	16.7

Figure 7 plots maximum production rate vs. creek discharge for all data collected, with a second-order polynomial trend line fit to the data. These production rate values were not independently verified by the USACE. Excluding the September 2011 flood, the range of discharge rates captured represents the typical range expected at this site during any year. The figure shows the dependence of bed load on discharge. The estimated production rates in Table 2 (based on the 2 ft collector extraction rates) agree well with the production curve in Figure 7 at the lower flow rates of 100 and 120 ft^3/sec, but less so for the 600 ft^3/sec flow rate condition. Peak measured production rate for the 30 ft collector was 100 yd^3/hour. At this rate, if sufficient bed load were available, the single 30 ft collector would move 876,000 yd^3/year. The high capacity of a single unit makes it possible to use structures in conjunction with collectors to maximize total capture with fewer collectors.

Visual inspection of the hopper and other system components were made at least monthly over the course of the year. No significant wear or corrosion was shown on any parts although the urethane coating on the mild steel hull did sustain scouring and erosion. No repairs have been required other than those associated with initial system configuration as a result of the flood in

September 2011 and vandalism that damaged the power and control conduit leading to the dredge pump. Additional automation and instrumentation was added with the return water tank that included a variable level control and high-level switch that assists with balancing the system.

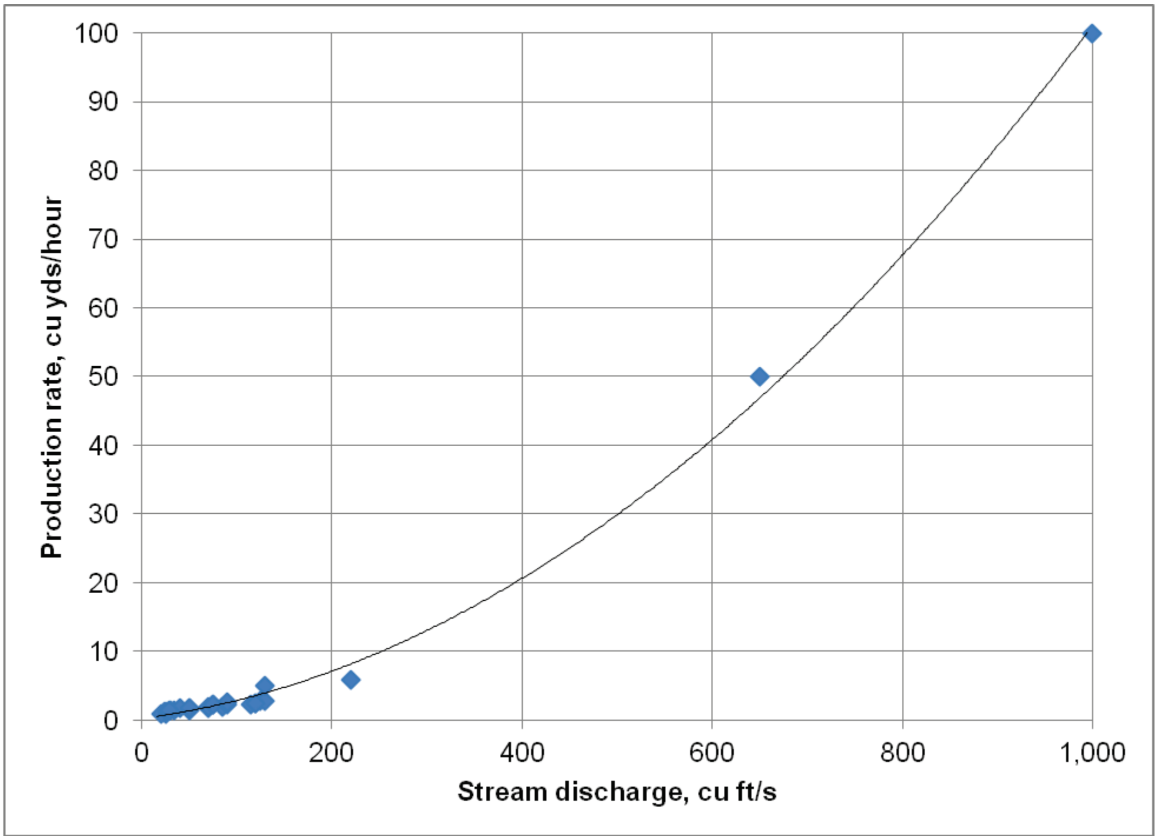

Figure 7. Sediment collector production curve.

LESSONS LEARNED: Initial deployment of new systems is an opportunity to inform design and improve installation procedures. The following list describes lessons learned during the demonstration project:

- All electrical components should be well above potential flood water levels.
- Pipelines should be as straight as possible, with no sharp turns, limiting the potential for air to be trapped in the lines.
- When operating the system with return flow, a sufficiently large water storage container should be available at the discharge point to prevent air intrusion during pump start-up and to ensure that an acceptable slurry specific gravity is maintained.
- Experience at Fountain Creek suggests that the return flow pump is a worthwhile investment, reducing risk associated with grade control, and that the return flow also prevented the collector from being clogged from surges of sediment that accumulated in the hopper (i.e., the return flow refluidizes these sediment *slugs* in the hopper and meters it into the suction ports).
- Accurate survey for grade control during installation is essential both at the discharge point and hopper.

  - Elevation of the hopper directly controls elevation of the bed during operation.
  - Elevation of the pipeline discharge point (relative to the hopper) controls the size of the return flow pump, or required head difference if attempting to run without a return flow pump.

- As with any industrial operation, measures must be taken to ensure that unauthorized personnel do not gain access to the material management equipment (separator and stacker). The 6 ft tall fence around the demonstration project site was insufficient to prevent the curious from gaining access to the dangerous electrical and mechanical equipment. Yard lighting is recommended for night operations.
- Screen configuration and size should be based on the aggregate particle sizes in bedload. This demonstration project selected the standard coarse sand, stainless steel, round bar stock with a 3/8 in. spacing in lieu of recommended vibratory screens. During periods of low flow, larger aggregate can align in the screen apertures, resulting in bridging. Vibrating screens or jet systems could be added to offset this requirement.
- To ensure that stream flow and bedload are delivered across the collector screens, appropriate permanent or temporary cross-vane structures are recommended. Tangential interception of the stream flow by the collector screens can exacerbate the aforementioned screen-bridging issues that were identified.
- Careful collaboration between the technology vendor (or other expert), engineer responsible for system/site design, and construction contractor is essential to avoid additional cost associated with field modifications during installation and initial testing. Design-build may be the best procurement mechanism for initial full-scale applications.

RECOMMENDED GENERAL APPROACH FOR COLLECTOR PROJECTS: Sediment collector technology should be considered when substantial quantities of sediment selected for removal are being transported as bedload. Recommended key steps in scoping, design, construction, and operation of a sediment collector project are identified below:

Predesign analysis. Appropriate analyses should be conducted to determine sediment transport processes, and expert advice should be solicited to determine if a collector is feasible for each site. Key parameters that should be investigated to determine if a collector project is feasible include the following:

- Sediment transport (size and rate): Typically measured through deployment of a 2 to 6 ft collector emplaced and operated during varying stream flow conditions (Lipscomb et al. 2005).
- Transport processes and pathways: Typically assessed through combination of expertise, field data and inspection, and application of numerical models.
- Sediment management: Identify potential placement locations and methods of conveyance.
- Operations plan: Identify who will be responsible for operating and maintaining the system after construction.
- Benefits analysis: Compare cost, both financial and environmental, to alternative methods to identify the least-cost method of removal.

Design. After the decision to install a collector has been made, design of the plant should be conducted by an experienced engineer consulting with the system developer or other expert in collector installation. Major components of design analyses include the following:

- Collector design: Based on data collected and analyses conducted in the predesign phase, consult with the system developer to determine the appropriate configuration of the full-scale collector system.
- Placement area design/plan: Design the placement area and plan operations to manage the sediment load anticipated. Contingencies for minimal oversight should be considered.

  - If not conducted during the redesign phase, it may be necessary to collect more data or conduct additional analyses to determine the rate of sediment that must be handled.
  - Placement area options range from direct discharge to a complete mechanical separation plant like the one used at Fountain Creek.

- Pump and pipeline design: Pipeline layout should minimize head loss, prevent air from being trapped, and follow the shortest possible route. Pump size will be a function of sediments, collector size and configuration, placement area design, and pipeline configuration.
- Electronic control and electrical design: Electronic controls and electrical wiring for the collector system must be designed. The control system should be designed with the collaboration of the system vendor.
- Final site design: Other design features typical of a civil project such as grading, drainage, roads, utilities, lighting, site safety, etc. should be considered.

Construction. The system should be installed by a qualified construction contractor with an expert in collector installation on staff. The demonstration project identified some issues to consider during construction, listed below:

- Construction quality control (QC): Lessons learned during the pilot highlighted the importance of QC during construction. Elevation tolerances, pipeline layout, and electrical wiring all had issues at Fountain Creek that could have been eliminated through QC during construction.
- Initial testing: Like any new system, initial testing should be conducted to determine if the system is operating as intended.

Operations and maintenance. After construction, the system should be monitored to ensure that it is functioning as designed. Some topics for consideration after construction include the following:

- Monitoring: System components (collectors, pumps, electronics, etc.) and environmental factors (sediment size and transport rate, flow rate, etc.) should be monitored to assess performance and to inform system maintenance or tuning.
- System tuning: Because of the uncertainty associated with modeling and measuring sediment transport, it is likely that actual production will be different than predicted. It may be possible to modify system configuration to optimize performance. Plan to re-evaluate system layout after monitoring data have been gathered and analyzed.

Length of monitoring duration necessary to make system tuning decisions will, of course, depend on which system design aspects are being evaluated. The decision to relocate certain Fountain Creek electrical components well above potential flood water levels happened immediately after the components were flooded. Something like a system reconfiguration may take longer to more accurately reassess site specific conditions (e.g., optimum sediment transport volumes and patterns).

CONCLUSIONS: This DOER TN is Part 2 of a series demonstrating innovative methods to enable sustainable sediment management to reduce dredging requirements. This TN presents application of sediment collector technology in Fountain Creek, Pueblo, CO, and discusses how it might be applied to reduce USACE navigation dredging. The installation successfully demonstrated the technology, specifically that collector technology

- works with coarse sediments in a shallow unidirectional flow environment
- has minimal maintenance costs over a 1 yr deployment
- survives record floods with minimal damage
- is capable of producing up to 100 yd^3 per hour with a single 30 ft collector
- is relatively inexpensive and easy to deploy without specialized equipment.

Further investigation of collector technology through a larger-scale demonstration at a navigation project is recommended. Future demonstrations should consider testing application in areas with wave dominated transport, application with finer sediments, application in deeper water, and different placement options.

POINTS OF CONTACT: For additional information on sediment minimization to reduce dredging, contact Robert Thomas (409-766-3179), *Robert.C.Thomas@usace.army.mil;* Timothy Welp (601-634-2083), *Timothy.L.Welp@usace.army.mil*; and/or the DOER Program Manager, Dr. Todd Bridges (601-634-3626), *Todd.S.Bridges@usace.army.mil* . This technical note should be cited as follows:

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